SHARC Melody Platform with Auto Room Tuner (ART) Technology

Optimized Surround Sound for the Mass Market

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"IDC estimates that the combined worldwide revenue of DVD recorders, home theater-in-a-box (HTiB) systems, and automotive DVD units will reach more than $11 billion by 2005."

Source: Worldwide DVD Player Revenue by Form Factor, 2002-2007, IDC

"Thanks to the popularity of DVDs, consumers in the past few years have stampeded to upgrade home theaters, the large-screen TV and stereo setups that simulate a movie-theater environment."

BusinessWeek, July 21, 2003

"Factory-level sales [of home-theater-in-a-box systems] surged 12.8 percent in 2002 to $896 million, and CEA forecasts continued growth through at least 2006."

Digital America 2003, The U.S. Consumer Electronics Industry, The Consumer Electronics Association

Optimized Surround Sound for the Mass Market

Digital audio is introducing a bold new sound in consumer audio and home theater systems. Several factors are converging to bring high-end, surround sound audio to mass-market buyers: the rise of the DVD, new formats for multichannel audio, and widespread use of digital signal processors (DSPs) in audio systems. With sales of home audio systems expected to continue booming growth, manufacturers seek ways to differentiate their products, quickly implement new features across a range of models, secure market share, and reduce their system and development costs.

Analog Devices, Inc. tunes into these needs with the latest SHARC Processor family members integrated into the SHARC® Melody® Platform, which implements Auto Room Tuner™ (ART™) technology to simplify the setup of complex audio systems while enabling a dramatically better listening experience. In a typical application, ART software resides on the SHARC Melody Platform within a surround sound receiver. The ART technology automatically measures and corrects the acoustics of the multichannel sound system for the specific room where the system is being set up, compensating for non-ideal room acoustics and speaker response.

As part of the SHARC Melody Platform's complete package of audio processing features that build on Analog Devices' established record in professional audio, ART brings manufacturers a new advantage in creating products that are designed and priced for the mass market. Developers can now benefit from cost-effective—and consumer-friendly—technology to offer the average consumer the rich surround sound once enjoyed exclusively at concert halls and movie theaters.

Trends Surround Consumers with Sound

Realistic surround sound has for years been reserved for audiophiles willing and able to pay the premium for upscale components and custom installation by trained technicians. Advances in technology are leading to lower costs and falling prices that are allowing manufacturers to bring surround sound and multichannel audio to many more ears.

An especially big hit is the home theater system, especially home-theater-in-a-box (HTiB) packages that conveniently bundle a complete set of audio components with the necessary connections. At retail prices starting around $300 and up for HTiB systems that include an AVR, DVD player, and six speakers, it's little wonder that surround sound is increasingly popular among a DVD-buying public.

As more compelling sound finds its place in the mass market, however, audio developers are discovering new challenges as well as new opportunities. For example, setting up a surround sound system has been complicated; even high-end audio systems tend not to be configured to best effect. Speakers are often placed in poor locations because of space constraints in the home. Users seldom perform the usual manual procedure of calibrating the delay and gain of each speaker. Bass management parameters may be left in an incorrect state; speakers may be wired out-of-phase or left disconnected. Although committed audio enthusiasts may hire a technician or take delight in handling the details themselves, manufacturers recognize the average person will not be satisfied unless surround sound installation becomes much more consumer-friendly.

Target Hardware Specifications

Hardware Configuration

- Target Processor: SHARC ADSP-21xxx
- External Memory
  - Flash ROM: 1MB (1M*8 bit width)
  - SRAM: 1MB (8 bit width; 256K x 32 bits)
- Oscillator
- Microphone (OEM-provided)

Host Interface

- Serial Peripheral Interface (SPI)
- Clock/Strobe/MISO/MOSI

Serial Audio Interface Configurations

- Sampling frequency range for auto setup: 44.1 kHz or 48 kHz
- Sampling frequency range for room equalizer: 32 kHz–192 kHz (dependent upon sampling frequency of input signal)
- Input ports configuration: maximum 10 channels
- Output ports configuration: maximum 10 channels

The ART Concept

Analog Devices' ART technology for automatic equalization and calibration provides effective, economical capabilities that audio system manufacturers can use to meet challenges and opportunities alike. The ART concept takes advantage of the ubiquity of DSPs in today's surround sound gear. These DSPs are getting less expensive and more powerful, while the audio decoding algorithms they were originally intended to implement have been standardized. As a result, built-in processing capacity is available to improve sound quality.

One special advantage of hosting ART software as part of the SHARC Melody Platform within a surround sound system is that room equalization integrates directly with the other functions of the receiver—a marked improvement over earlier systems that required an expensive and hard-to-use external component to perform equalization. The ART approach therefore minimizes the cost of the incremental elements needed to optimize sound; the addition of ART software and a microphone get the job done. Another significant advantage is that SHARC Processors offer 32-bit floating-point DSP performance for a competitive system cost, ensuring high performance and cost-effectiveness for the complete set of audio processing functions performed on-chip.

What's more, ART technology on the SHARC Melody Platform addresses the trend for HTiB packages to use a subwoofer and small satellites. The sound quality of inexpensive satellite speakers can be enhanced significantly by appropriate room equalization, helping developers of audio systems to deliver a rewarding experience at a lower cost.

Factors Influencing Sound Quality

Why has achieving optimum room equalization been a complex problem? The answer is audible in the numerous factors and endless variations that come to play in real-world listening environments. Getting down to fundamentals, the quality of sound playback is affected mainly by the quality of the loudspeakers, the acoustics of the listening space, and the arrangement of the speakers with respect to the listener.

A high-quality loudspeaker reproduces sound over a large frequency range with only minor variations in frontally radiated power as a function of frequency. Poor quality loudspeakers tend to have non-uniform frequency responses, boosting certain frequency ranges while attenuating others.

Another important attribute of loudspeakers is their directivity, which varies as a function of frequency. The directivity of a loudspeaker depends on the size and shape of the enclosure and the properties of the transducers used. Loudspeakers tend to radiate very high frequency sound only in the direction where the speaker is pointing, whereas very low frequency sound radiates equally in all directions. Consequently, the frequency response of a loudspeaker measured in anechoic (echo-free) conditions varies greatly as a function of measurement angle.

Listening spaces have very complicated frequency responses, stemming from the reflections of sound off the various surfaces in the room. The resulting reverberation has a time response characterized by a few prominent early reflections followed by a dense collection of reflections from all directions, which is often called late, diffuse reverberation. The frequency response of a room will contain prominent peaks at low frequencies that correspond to vibrational modes of the room; the frequencies of the peaks can be calculated simply given the dimensions of the room. At higher frequencies, the density of modes becomes so high that the frequency response becomes statistical in nature and is characterized by closely spaced peaks and valleys.

The overall shape of the frequency response depends on the absorption characteristics of materials in the room; because most porous materials absorb more readily at high frequencies, room responses tend to have less amplitude at high frequencies. Room responses are best described statistically except at low frequencies or at early times. As the measurement point is moved in the room, the fine-grain details of the response change imperceptibly, but the overall envelope of the response does not change much.

Loudspeakers are best placed at equal distances from the listener, and at angles that depend on the playback format. The optimum stereo placement is at +/- 30 degrees in relation to the listener. In 5.1 surround sound systems, for instance, the center speaker should be placed directly in front of the listener, and the surround speakers should be placed at 110 degrees at each side. The placement of the subwoofer is not critical. Most listening situations do not permit ideal speaker placements with respect to the listener, which results in improper balance of the sound image. When a listener is closer to one speaker than another, the closer speaker will dominate the sound image because its sound arrives earlier and is also louder. In addition, surround sound systems may include speakers from different manufacturers that may not be well matched acoustically.

As a well-designed room equalization system, ART software attempts to compensate for all these factors: the frequency response and directivity of each loudspeaker, the frequency response of the room, the position of the listener in relation to the loudspeakers, and incorrect installation.

Design Points: Consumer-Friendly and Feature-Packed

ART technology on the SHARC Melody Platform was designed for consumer market applications from the start. The software has been implemented as a fully automatic system that enables inexperienced users to very easily and quickly achieve results in their own rooms. The approach also promises to remove a barrier for more tech-savvy buyers that—perceiving that more features equate to greater complexity—may have been reluctant to install surround sound because they lacked the time or money for an effective installation.

While designed for competitively priced applications, the results possible with ART software rival the best available high-end room equalizers. The ART algorithm is a high-quality implementation based on state-of-the-art signal processing and pattern-recognition techniques. Manufacturers gain a differentiating advantage in bringing excellent surround sound to a mass market that values simple operation as highly as the latest new features.

The design of ART technology is informed by the following requirements:

- Automatic, robust, foolproof operation
- Single, fast measurement; only a single point—the main listening position—is measured
- No prior knowledge is required about speakers, room, and other parameters; all information about the audio system is determined automatically
- Available on an affordable SHARC Melody Platform
- Improve sound quality across a large sweet spot in a room, to the benefit of multiple listeners

Best Surround Sound Optimization—Automatically

Using ART technology to measure and correct the response of a multichannel audio system is exceptionally consumer-friendly. After installing the receiver and speakers, the user positions a microphone at the main listening position. (The receiver OEM supplies the microphone, which may be placed inside the remote control to eliminate the need for a separate microphone tethered to the receiver.) The user then initiates the calibration and equalization process through the receiver's remote control.

The ART software measures the sound system by emitting noises through each loudspeaker. During calibration the user hears a pink noise measurement signal, which is warmer-sounding than white noise, and much less annoying than the clicks, chirps, and squawks used by other systems. Each noise lasts 1.5 seconds followed by a few seconds of silence. The microphone at the listener's position records these noises and the SHARC Processor within the receiver analyzes the resulting signals.

The ART algorithm works in concert with the SHARC Processor to calculate an abundance of information about the user's sound system, including the sound pressure level (SPL) of each speaker, the distance of each speaker from the listener, and the frequency response of each speaker. This information is used to improve audio quality by applying gain, delay, and tone correction during sound playback. The ART software also automatically configures bass management parameters. The algorithm corrects deficiencies in the complete sound system as actually installed, including non-uniform speaker response and directivities, room reflections and reverberation, less-than-ideal speaker and listener positions, and incorrect installation.

Except for initiating the sequence, users do not have to be aware (unless they prefer) of the sophisticated process underway. Only a single, fast measurement is required at the prime listening position. In just a very few minutes—instead of the long time that would be needed to complete the steps manually—the ART software and the SHARC Processor measure, calculate, and compensate for the installation's actual acoustics. The outcome is significantly better sound quality, not only at the main listening location but also throughout the room. Users can hear the difference for themselves: The ability to enable and disable equalization during playback allows listeners to appreciate the improvement.

The convenience, speed, and results make it appealing for users to recalibrate their systems anytime they make a change to their rooms such as moving the furniture around, or if they relocate their surround sound equipment to another space.

Auto Setup Parameters

After taking the single measurement of each audio channel described earlier, the ART auto setup function detects specific parameters that include:

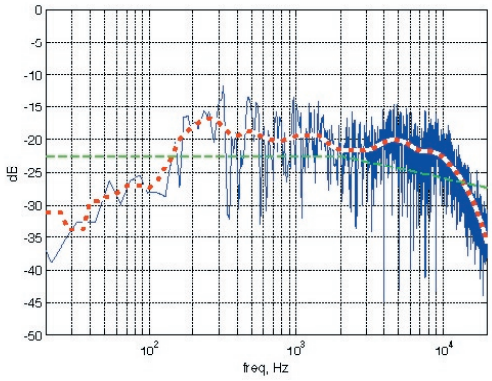
- Speaker presence. Did the user remember to connect each speaker?
- Inverted polarity. Was the speaker wired out-of-phase?
- Sound Pressure Level (SPL) of speaker in dBC. This is the same information that would be given by an SPL meter set to C-weighting, and is a measurement of perceived loudness used to set speaker levels.
- Distance from listener (delay in msec). This measurement is used to set the compensation delay to each speaker. Without ART functionality, the classic approach involves measuring these distances with a tape measure.
- Identifying the types of speakers. Is the speaker a subwoofer? Is the speaker a large or small satellite? The latter information is necessary for bass-management configuration. The speaker is considered a large satellite if it reproduces frequencies below 80 Hz.
- Determining the roll off frequency of each main speaker and subwoofer in Hz. This is another required parameter for proper bass management.

Comparison: Before and After ART

An ideal speaker would have a perfectly "flat" response in an echo-free environment. After accounting for ideal listening room acoustics, the response should be flat to 2 kHz and then roll off at -1.5 dB/octave at higher frequencies. The dotted line represents the target curve depicting this ideal response. ART adjusts the speaker response to better match the response of an ideal speaker in an ideal listening room.

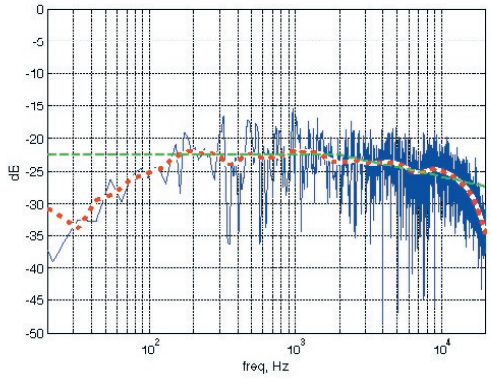
Also shown is that ART adjusts the overall gain of the speaker. In the before figure, the gain is too high (that is, the speaker is too loud). In the after figure, the gain has been lowered to the ideal target level.

Before



Dotted line shows spectrum before correction; dashed line shows target spectrum.

After



Dotted line shows spectrum after correction; dashed line shows target spectrum.

Auto Equalization and Compensation

Based on parameters and data generated by analyzing the Auto Setup, the ART algorithm and the SHARC Processor calculate coefficients then used to perform auto equalization and compensation. These adjustments include:

- Compensating delay for each speaker, in msec. Sounds from different speakers will reach the listener simultaneously. If the delays are not compensated for, the listener tends to hear the sound as coming from the closest loudspeaker.
- Compensating gain for each speaker, in dB. Compensating gain for each speaker is very important to restore the proper volume balance between loudspeakers.
- Compensating equalization parameters for speaker. This adjustment consists of tonal equalization to compensate for non-ideal speaker and room response. Equalization is performed by parametric equalizers. Each band has the following parameters: center frequency, gain, and bandwidth (Q). The number of bands to apply per channel is set by the receiver OEM.
- Graphical display of equalization curves for editing by users. Graphical display and editing accommodates audio buffs that like to make their own adjustments. This feature is possible because ART uses parametric equalization filters. In addition, receiver manufacturers have the option to allow users to perform manual equalization based on user-defined coefficients.

Flexibility and Faster Time-to-Market

Because the ability to address mass-market consumer audio guides the direction of ART technology, Analog Devices supports this software with design and development capabilities to match. Designers of surround sound receivers benefit from customizable capabilities, reduced development risk and cost, and faster time-to-market for a range of models with different feature sets and at different price points.

Among the flexible and customizable features of ART software are:

- Support for arbitrary speaker configurations. ART supports any number of channels (ports). It auto-detects if each channel is detected and whether each channel is connected to a subwoofer or a loudspeaker. While this capability benefits the user, it also affords manufacturers more flexibility in packaging systems that include different numbers and types of speakers.
- Support for OEM-provided microphones. ART software has the ability to compensate for a non-flat frequency response curve (the flatter the curve, the better for measurement), which permits the use of an inexpensive microphone for measurement. System designers specify the frequency response for the microphone of their choice.

- Customizable user interface. Typically, the receiver would display a video screen showing which channel is being measured and the information about that channel. The receiver OEM can readily adapt the ART interface, adding to consumer usability and product differentiation.
- Ability to specify custom target equalizations, each with a characteristic sound, that can be preset for specific market segments. Possibilities include settings such as “classical” or “rock.”

Development risk and cost are minimized and time-to-market is accelerated by the fact that current-generation SHARC Processors integrate all necessary audio functions, including the ART algorithm, within the chipset. Not only do these processors offer industry-leading floating-point performance, but they also enable at least twice the performance of single-MAC (multiply accumulate) fixed-point devices. In addition, they implement early support for the latest audio decoders and postprocessors (such as Dolby® ProLogic® IIx and Microsoft® Windows Media® 9 Audio Professional) and enough on-chip memory to support studio-quality audio processing.

Furthermore, the processors’ programmability enables the flexibility to upgrade designs with additional features and emerging standards. With the SHARC Processor family, developers do not have to use external devices or software add-ons to implement functionality. This kind of integrated approach is not only desirable, but a prerequisite, to achieve the commodity pricing and rapid cycle time that manufacturers require to profit from bringing an ever-richer audio experience to the average consumer.

All SHARC Processors are fully supported by Analog Devices’ VisualDSP++™ integrated development environment, a complete set of software tools that provides a highly optimized C++ compiler and a graphical development environment.

ART and SHARC Melody Platform—In Harmony for the Consumer Audio Market

ART technology on Analog Devices’ powerful SHARC Melody Platform enables audio system developers to benefit from a growing market opportunity by providing the lush, multichannel sound that appeals to buyers of home audio receivers. By easing the setup of home theater systems and compensating for non-ideal acoustic environments and speaker responses—at the right price point for the mass market—ART software and the SHARC Melody Platform turn an otherwise complex process into a consumer-friendly experience with results that buyers will hear.

Because ART technology is part of the comprehensive audio processing and system development environment provided by the SHARC Melody Platform, developers are positioned to speed their product introductions to mainstream consumers eager for high-quality audio that until recently was accessible only to aficionados and professionals.

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